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Port and Harbor Security

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Background

9/11 was a sobering wake-up call to terrorism's threat to everyone's homeland. Beyond the tragedy of lost lives, the economic and social impact on our world has been immense. Responding to this, and recognizing the potential of technology to counter terrorism, we formed the Global Homeland Security Technical Group (http://spie.org/Membership/index.cfm?fuseaction=TG_HomelandSecurity) (GHSTG). The GHSTG's mission is "To stimulate & focus the optics and photonics technology community's contributions to enhance safety, improve the sense of well being & counter terrorist threats." In addition to our efforts to help connect small businesses and stimulate standards, we have two other major initiatives: Drinking Water Safety (chaired by Dan Kroll, Hach Industries), and Port and Harbor Security (chaired by Michael DeWeert, BAE Systems). We focus on the Port and Harbor Security initiative, requirements, and key technologies. Ports and Harbors serve vital economic and homeland defense functions. In the U.S. over 95 percent of the nation's overseas cargo moves through our ports. Internationally 5.8 billion tons of goods were traded by sea in 2001 accounting for over 80 percent of world trade by volume. Cruise ships calling at U.S. ports carry over 6 million passengers per year.[1] Thus, ports are both entry points and high-value targets for terrorists.

SPIE's Port & Harbor Security initiative is dedicated to promoting development of photonic technologies and applications for use in deterrence, prevention, and detection of terrorist actions against ports and harbors. The initiative addresses container and shipping security, detection and interdiction of marine vehicles and swimmers, security against piracy and hijacking, detection of underwater CBRNE (chemical, biological, radiological, nuclear, and explosive) threats, and countering landward-side threats. In

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addition, the initiative includes sensor integration into manned and unmanned platforms, sensor networking and fusion, requirements and standards for homeland security, and integration with air defense, law enforcement and first responders. The inaugural workshop outlined needs and technology opportunities, and stimulated the initiative.[1]

DHS Approach and Requirements

The Department of Homeland Security (DHS) established a layered approach[2]: Overseas, In transit, In US Waters and on US Shores.

From Overseas and In Transit: 16 million containers a year enter the U.S., presenting a need to detect intrusion and insure freedom from terrorist activities. The security measures must be compatible with the economic necessity of rapid transit, especially for perishable and seasonal goods. An appropriate balance is needed between security and freedom – between inspecting every container and keeping trade moving.[2] Beyond the requirement of a tamper detector on the door, Phil Young pointed out the needs to have an internal sensor detecting entry *through* the side. The container volume violation must be quickly and accurately readable by the customs and border patrol.[1] A global positioning capability could provide a real-time location history. The economic *benefit* of real time information may offset the additional cost per container. In-port container inspections can use large-scale gamma ray and x-ray imaging systems to safely and efficiently screen for contraband, including weapons of mass destruction. Fiber-optics probes can non-intrusively inspect container interiors and offer excellent opportunities for image processing software.

In US Waters and on US Shores Preventing terrorists from entering sensitive areas of the transportation system is important and funded ($50 M, FY04) by DHS's Transportation Security Administration.[2] Similar identification needs exist for crewmembers. Optical and photonic technology could provide unique biometric identifiers. Perimeter-penetration detection benefits from night vision capability, but it is important to differentiate between infrared sensors and low-light visible cameras. Low-light cameras typically cost less, but have less capability than long-wavelength thermal imagers. 24/7 monitoring of extensive perimeters requires cost-effective, robust and

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reliable imaging systems and networks, as well as sophisticated algorithms and software to provide automatic detection, warning, and tracking.

Military Needs

Naval Port and Harbor security faces additional tasks and requirements. Key Navy sources of information include: Afloat Anti-Terrorism / Force protection Program Office (PMS 480); Ashore Anti-Terrorism /Force Protection Program Office (CNI); Fleet Forces Command – N9; Maritime Force Protection Command (MARFPCOM); Navy Anti-Terrorism Technology Coordination Office (NATTCO) and ATFP related documents associated with the Joint Capability Integration and Development System (JCIDS).

NATTCO- the Navy Anti-Terrorism Technology Coordination Office (contact: John R. Tanke, TankeJR@nswc.navy.mil) is sponsored by CNI and PMS 480 and collects information on candidate commercial off-the-shelf/government off-the-shelf (COTS/GOTS) Anti-Terrorism and Force Protection (AT/FP) related technologies. It maps technologies to existing and approved Mission Essential AT/FP Tasks. In addition to assessing technologies and the potential for reduced manning, NATTCO assists capability needs derivations while evaluating operational feasibility, technical/programmatic risks, and transition potential.

Joint Capabilities Integrated Development Systems (JCIDS) analyses are key to understanding Warfighter requirements and operational contexts. JCIDS documents are supported by several key analyses. The Functional Area Analysis (FAA) identifies the operational task, conditions, and standards needed to accomplish the military objectives and results with tasks to be accomplished. The Functional Needs Analysis (FNA) assesses the ability of current and programmed capabilities to accomplish the tasks resulting in a list of capability gaps. The Functional Solutions Analysis (FSA) is an operational based assessment conducted across a broad range of available considerations that include doctrine, organization, training, material solutions (technologies), leadership, personnel and facilities (DOTMLPF). The FSA includes an analysis of material approaches that is akin to a cursory analysis of alternatives that helps point decision

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makers to material solutions that show the most potential for addressing identified capability gaps. The last analytical component that is sometimes undertaken is a Post Independent Analysis that is akin to an independent review of the method, rigor and apparent recommendations resulting from the FSA. Once completed, these analyses form the underpinnings of the initial JCIDS "Initial Capabilities Document" (ICD).

The Navy has concerns with infiltration from the land and must establish entry control points and perimeter security. Combat swimmers and mini-submarines are also of concern. Effective systems should provide identification as well as detection and classification of these threats, with specific requirements addressed in ICDs.

Imaging Technologies

While underwater surveillance and detection depends heavily on acoustics, there is a growing recognition that acoustics alone cannot provide a complete solution, especially in shallow water with complex bottom topography. Optical systems have advantages in spatial resolution, compactness, speed of deployment, and human interpretation. Consequently, optical techniques developed for de-mining are now being adapted for homeland security. We foresee that both optical and acoustic components will eventually be integrated into "systems-of-systems" for protection.

The most cost-effective way to survey a large area is via aerial passive imaging. The largest impediment to airborne imaging is seeing through the wavy sea surface, which creates distortions that can make underwater objects unrecognizable. In addition, surface reflections, especially glints from the sun and moon, are typically much brighter than the light reflected from subsurface objects. Finally, surface waves produce foam, which is highly reflective and highly scattering – it is generally considered impossible to image through foam. Unaided human vision has difficulty dealing with surface effects, but multi-spectral digital imaging and high-speed multi-frame image processing can greatly reduce glints, distortions, and foam obscuration. Figure 1 shows an example of the results of such processing. Using information from many frames, obscuring surface effects are removed, clearly revealing the sea floor.

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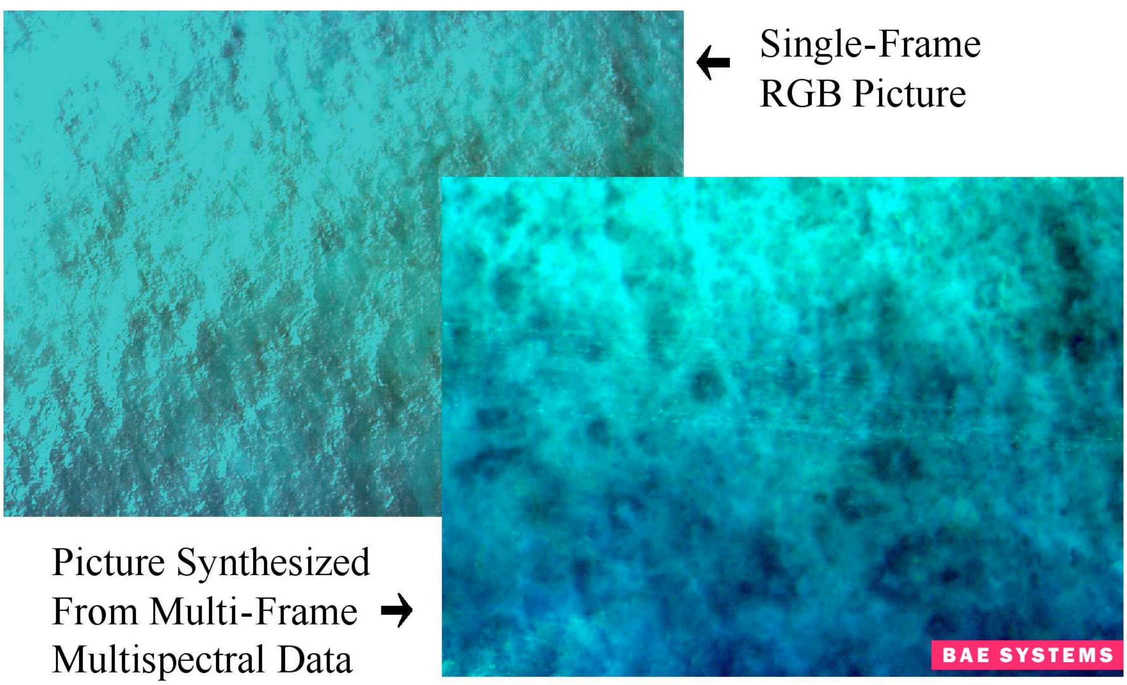
Once the sea-surface effects have been handled, water's optical properties problems arise. Water "drinks" light – the total reflectance of deep water may be just 2%, and the exponential attenuation of light in water causes the contrast of subsurface objects to decrease with depth. However, the water optical properties depend on wavelength in a predictable way. For example, Jerlov[3] developed a widely-used classification scheme that allows estimation of the optical properties over the entire visible spectrum from measurements at a few well-chosen wavelengths. With this information, it is possible to simultaneously classify an object and determine its depth. The ultimate depth at which passive detection can be achieved depends on the sensitivity and dynamic range of the optical system, the number of independent spectral bands it employs, and the quality of the spectral libraries available. The ultimate limit on depth penetration for passive imaging is scattering in the water. Even the clearest natural waters backscatter light, causing a fog-like foreground glow, reducing the target contrast. Scattering also blurs the outlines of distant objects – as the range increases, successively larger objects blur into the background.



Single-Frame RGB Picture

Picture Synthesized From Multi-Frame Multispectral Data

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Figure 1. Multi-frame image capture and processing can remove surface effects. Here, surface distortions and glints have been removed, clearly revealing bottom features including coral, sand, macro-algae, and reef damage caused by human activity.

When airborne imaging is impractical, underwater optical surveillance and detection can be accomplished via remotely-operated underwater vehicles (ROVs) and unmanned underwater vehicles (UUVs). UUVs equipped with visible cameras (using well-chosen spectral bands) can aid in maintaining underwater perimeters, and in identification of submerged threats. UUVs with optical capability can inspect hulls for explosives or other threats, relieving mammals and humans of dangerous tasks. (A human diver can easily become disoriented while investigating the acres of steel on the underside of an aircraft carrier.)

When cooling, volume, and power permit, active (lidar) imaging systems can reduce foreground haze, greatly improving target contrast and resolution. Fournier[1] reported that gating provides a 3-5 times increase in range over un-gated imagers. (Range gating transmits a short laser pulse, and after a time delay Δt opens the shutter. Light arriving before the shutter opens is blocked so that only light returning from a desired distance is detected.)

Conclusion

Port and Harbor Security is a daunting task to which optics and photonics offers significant solutions. We are pleased to report that the 2005 Defense and Security Symposium (DSS, Orlando, FL) will include reports on active and passive photonic systems operating from both airborne and subsurface platforms. In addition to imaging techniques, there are various photonic applications, such as total internal reflection fluorescence (TIRF), which can be used to "sniff" for traces of explosives or contaminants in marine. These non-imaging technologies are beyond the scope of this article, but will also be represented at DSS 2005. We encourage colleagues to join our technical group to help us to make our ports and harbors safer and more secure.

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